

National Aeronautics and  
Space Administration

**Jet Propulsion Laboratory**  
California Institute of Technology  
Pasadena, California

*JPL is able to apply its technologies,  
facilities, and expertise to assist our  
partners in product improvement and problem  
solving to reduce risk.*

***Contamination Control Engineering***

# JPL Contamination Control Engineering

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# Contamination Control Engineering for Payloads, Systems, and Missions



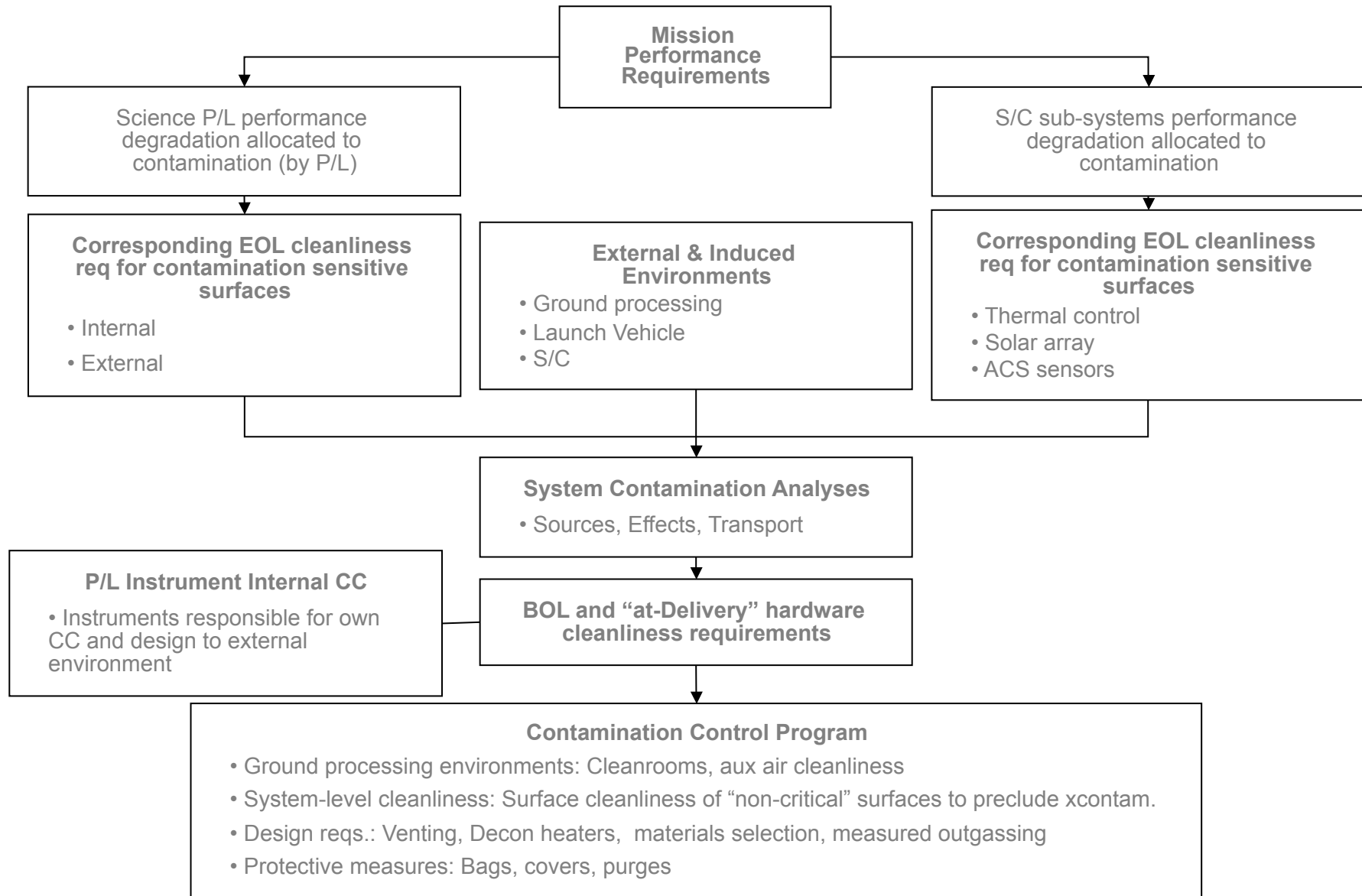
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- JPL has extensive expertise fielding contamination sensitive missions—in house and with our NASA/industry/academic partners
- Development and implementation of performance-driven cleanliness requirements for a wide range missions and payloads
  - UV-Vis-IR: GALEX, Dawn, Juno, WFPC-II, AIRS, TES, *et al*
  - Propulsion, thermal control, robotic sample acquisition systems
- Contamination control engineering across the mission life cycle:
  - System and payload requirements derivation, analysis, and contamination control implementation plans
  - Hardware Design, Risk trades, Requirements V-V
  - Assembly, Integration & Test planning and implementation
  - Launch site operations and launch vehicle/payload integration
  - Flight ops
- Personnel on staff have expertise with space materials development and flight experiments
  - LDEF, MATLAB, MSX, EOIM-3, SAMMES

# Contamination Control Process



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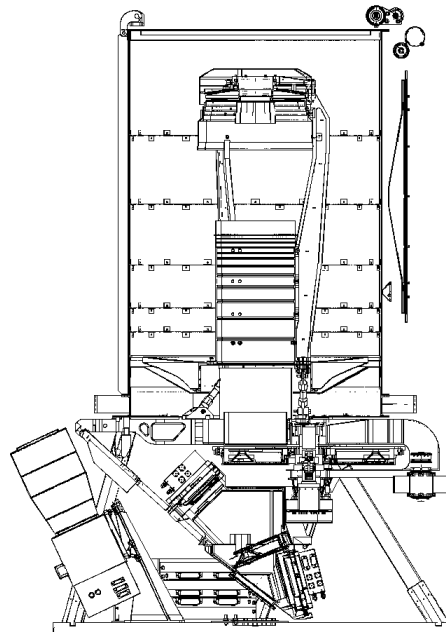


# GALEX—Galaxy Evolution Explorer

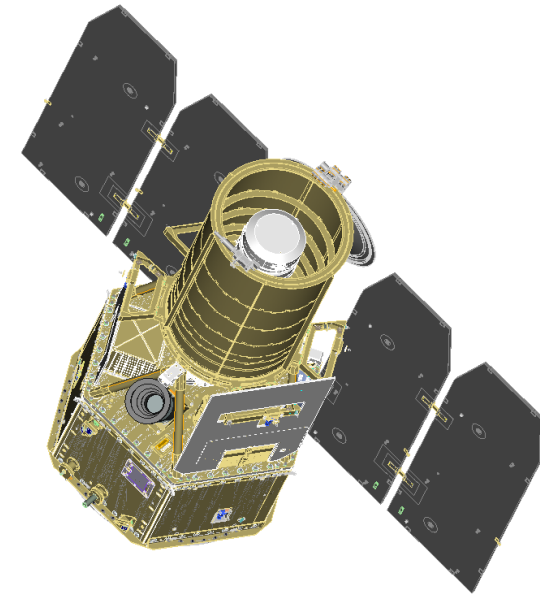


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- Telescope Aperture: 50 cm
- Optical Design
  - Modified Ritchey-Chretien with Aspheric corrected
  - Far UV band 0.135—0.180  $\mu$
  - Near UV 0.180—0.300  $\mu$
- System Cleanliness Requirements
  - Molecular: < 0.065  $\mu\text{g/cm}$
  - Particulate: < 1 PAC



GALEX Instrument Cut-Away View



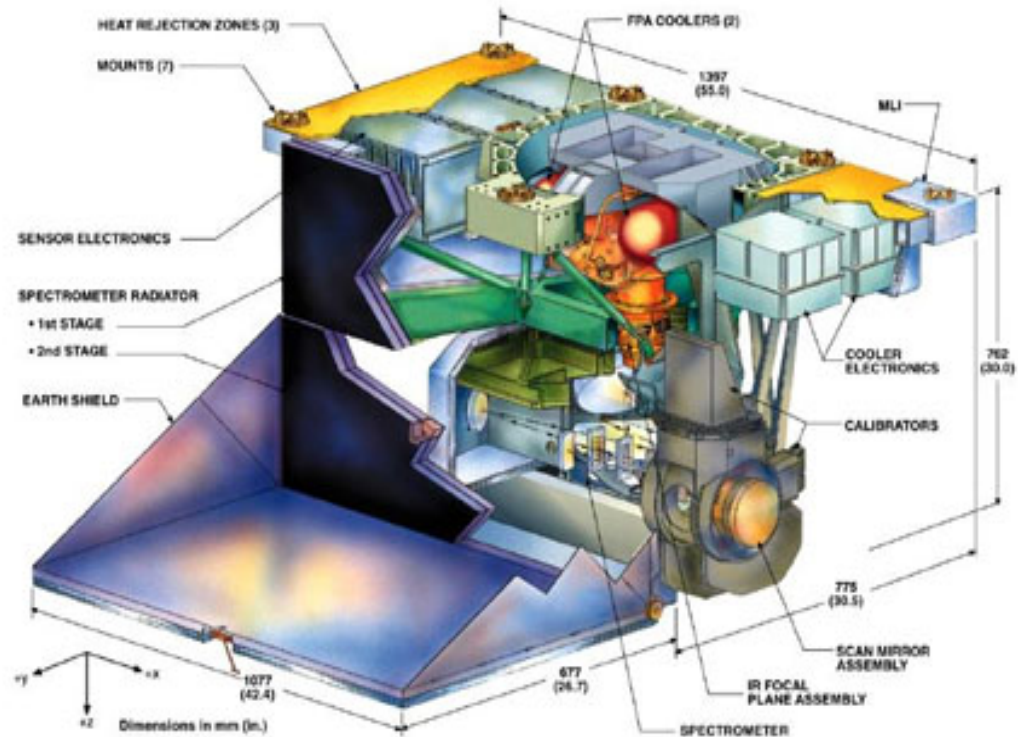
GALEX Satellite

# AIRS—Atmospheric Infrared Sounder



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- Spectral Range
  - IR 3.74 -- 15.4  $\mu\text{m}$
  - Visible/NIR 0.41--0.94  $\mu\text{m}$
- 58 K focal plane  
AIRS focal plane  
cryocooler, developed  
under contract  
with TRW
- Scanning Optics
- Cleanliness Requirements
  - Molecular:  $<1 \mu\text{g}/\text{cm}^2$
  - Particulate:  $< 0.02 \text{ PAC}$



# Specialized Capabilities



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- Molecular Contamination Spectral Effects (MCSE) Chamber
  - *In situ* measurement of optical effects of contamination
- Molecular Contamination Investigation Facility (MCIF)
  - Multiple temperature materials outgassing measurement
- Extensive library of materials outgassing data
  - MCIF (Modified MSFC-1559)
  - ASTM-E595
- Contamination Modeling
  - JPL-Developed molecular contamination transport codes
    - Space vacuum: System- and payload-level
    - Diffusion/convection environments: Habitable and extra-terrestrial atmospheric
    - System contamination issues associated with electric propulsion

# Contamination Transport Modeling at JPL



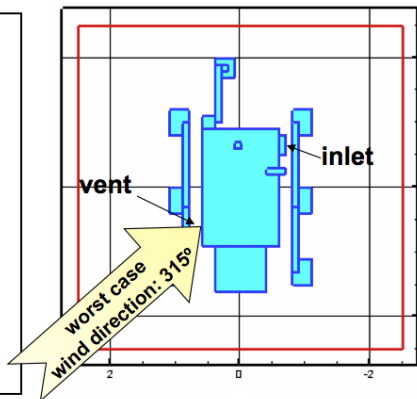
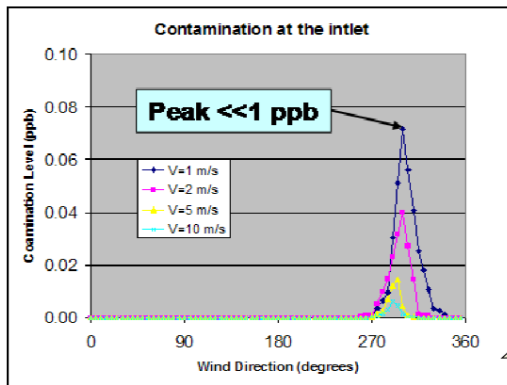
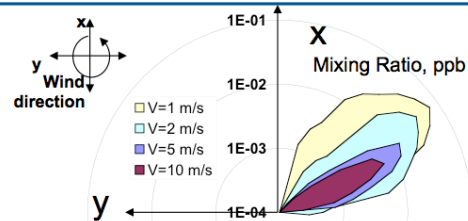
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## Contamination Transport Driven by Wind Direction

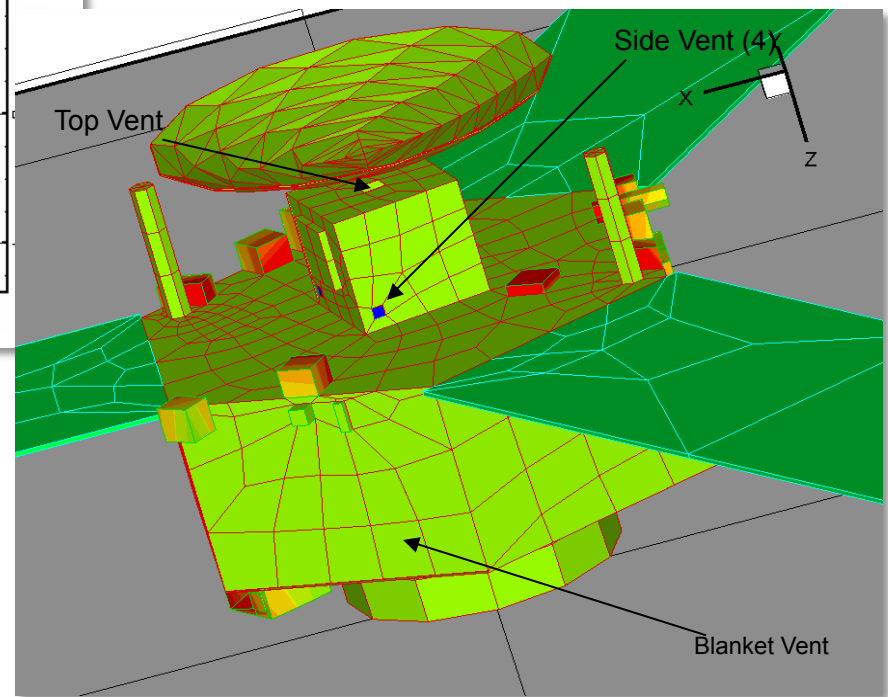


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- Concentration is a very strongly-peaked function of the wind direction.
- Worst case wind direction, were used to set the outgassing requirement.
- Vent flux requirement of 100 ng/cm<sup>2</sup>/hr set on the MSL vent, the largest source of contamination on the rover, easily meets the SAM Atmospheric Inlet contamination limit of 1 ppb.



## Vacuum Transport: Juno Vault Venting



Convection/Diffusion:  
MSL at Mars (8Torr CO<sub>2</sub>)

# Characterization of Contaminants



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## Molecular Contamination Spectral Effects (MCSE) Chamber

- Measure and evaluate the transmissive and reflective spectral effects of lenses and mirrors from VUV to Infrared wavelength. Turbo molecular drag (oil-free)– range: 1K to 5E-07 torr Dual cryo-pumped vacuum – total pressure: 1E-07 to 1E-09 torr
- Molecular Contamination Monitoring Capabilities
  - Quartz crystal microbalances (QCM): One cryo-quartz crystal microbalance (CQCM)– range 5K to 350K, 10 MHz Aluminum-plated crystals, Sensitivity:  $3.5 \times 10^{-9}$  gm/cm<sup>2</sup>/Hz
  - Residual Gas Analyzer (RGA)
- VUV-UV-Visible-NIR-IR Spectroscopy
  - Reflectance, Transmission
  - 120 nanometers to 25 microns
- Temperature control
  - K-Cell: +20 C to +165 C
  - Target control range: 15 K to 350 K
- BRDF (future capability)
  - Nd:Yag (1.06 nm)
  - CO<sub>2</sub> (10.6 nm)
  - HeNe (635 nm)

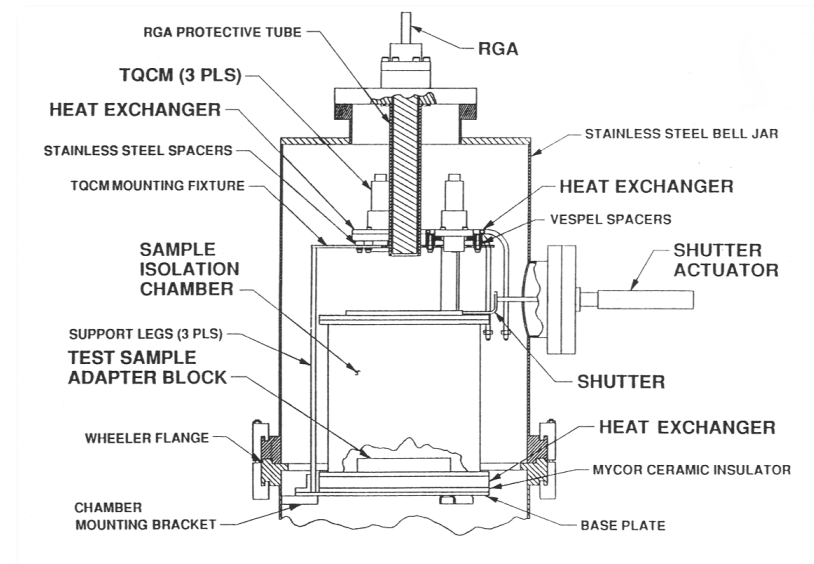


# Molecular Contamination Investigation Facility (MCIF)



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- **TEST CONFIGURATION AND CONDITIONS:** The test can be conducted using the provided hardware/electronic components (source contaminant), which would be placed inside the Knudsen-Cell type sample heat exchanger, inside the test chamber
- Pressure:  $< E-05$  Torr
- Three Quartz Crystal Microbalances
  - Independent temperature control
- Sample heat exchanger continuously variable to simulate mission operational temperature profile



# Conclusions



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- JPL has capabilities and expertise to successfully address contamination issues presented by space and habitable environments
- JPL has extensive experience fielding and managing contamination sensitive missions
- Excellent working relationship with the aerospace contamination control engineering community

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